Carbon stock dynamics in tropical rain forests of Uttara Kannada district, Western Ghats, India.

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CES Technical Report No. 96

October 2002

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ABSTRACT

Carbon stock dynamics was monitored in Uttara Kannada district, Western Ghats, Karnataka, for 10 years on 8 one-ha sampling area belonging to different management and forest categories The study was instituted during 1984 and later monitored till 1994. Our study indicates that in general the carbon stock has enhanced during the study period with an average growth of 1.008 t/ha/year. However, there were differences in carbon stocks in different management regimes. The minor forests that are subjected to intense human pressures had a negative growth rate i e, 0.237 t/ha/year, while the reserve forests have carbon assimilation rate of 1.31 t/ha/year. This indicates that the human pressure has certainly decreased the carbon accumulation in the forests of Uttara Kannada. Despite the anthropogenic pressure, the minor forests have higher carbon accumulation through recruits as compared to the reserve forests. Thus it is suggested that a management strategy is needed to look into enhancing recruitment patterns in minor forest that would become future carbon stocks

Key words: Carbon stock dynamics, tropical rain forests, Uttara Kannada, Western Ghats

Introduction

Increase of carbon dioxide (CO_2) in the atmosphere has become one of the global environmental issues in recent years because of its potential to change world climate (Brown and Lugo 1992 some more references from IPCC). Burning of fossil fuels and smoke emission by industries, particularly by the cement factories, are some of the reasons attributed for rise of atmospheric CO_2 (Brown and Lugo 1992) Increase in the rate of destruction of terrestrial vegetation has been considered as an important source contributing significant amount of carbon to the environment (Clark 1982; Houghton 1990, 1991) Due to terrestrial forest destruction, the carbon sink is diminishing, and the biomass extracted from these forests is also adding to carbon pool in the atmosphere. Tropical forests, known as the large stocks of carbon in the form of biomass, when disturbed release more CO_2 to the atmosphere (Palm *et al* 1986) Decimation of forest area in the tropics has been continuing over the past several decades The best option to reduce the increase of CO_2 in the atmosphere is considered to opt plantations and forest improvement that has the potential to replace burning of fossil fuels and to sequester carbon in bulk in the form of biomass.

Attempts have been made to estimate the rate of increase of CO_2 in the atmosphere by direct analysis of air and also, data have been presented using the information on conversion of forest area, soil carbon content and collating to the rate of emission and assimilation to highlight net flux of CO_2 Estimated values of net flux of CO_2 to the atmosphere ranged from 0.4 to 4.2 $x10^{15}$ Gt C/year (Palm *et al* 1986), and the estimates of annual carbon emission from forests at the global level are in the range of 0.4 -1.6 Gt C /year (Detwiler and Hall 1988) to 1.1 to 3.6 Gt C/year (Houghton 1991). Such a wide discrepancy in the estimates could be due to lack of proper information regarding the forest dynamics mainly the rate of production and degradation of forest Understanding of these is essential to arrive at precise rate of carbon fixation by a community and the applying it to regional and global level for estimating the change of CO_2 in the atmosphere This study focuses on the dynamics of standing biomass in tropical forest in the Western Ghats region of south-India and discusses on the carbon pools of different forests that are managed differently in the locality.

Study Site and Methodology

Study area

This study was conducted in Uttara Kannada district (lat , 13 55 to15 31 ; long, 74 9 to 75 10 E) which is a hilly forested terrain situated all most in the middle of the Western

Ghats in south India It is the northernmost coastal district of the Karnataka state bordered by the Arabian Sea in the west Geologically this is a transitional zone between the younger rocks of Archean shield of Indian peninsula Considering the climate, rainfall, topography and the major crops, the district can be divided in to 3 distinct zones. Coastal zone is a narrow strip, thickly populated, receiving more than 3500 mm annual rainfall Rice, coconut and ground nuts are the important crops in this zone. The crest line zone is forested, hilly tract, with low human population, receives 2500 mm rainfall annually. Horticulture and agriculture is restricted to broad wet valleys and hill-pockets. Betelnut and paddy are the important crops of this zone. Eastern flat maidan zone receives less rainfall (1200 mm/ year) and the population density is high. Paddy, cotton, ground nut, sugar cane, jowar and pulses are the important crops of this zone, mostly rainfed and to a little extent irrigated.

Comprising a total land area of 10,200 km^2, 80% of the total land area in the district is under the control of forest department. Recent report revealed that the forest cover is declining drastically and at present it is not more than 53% (Forest Survey of India, 1999) Efforts are being made to augment degraded forests and barren lands by planting timber, pulpwood, fuelwood species along with other miscellaneous species. Forests of the district are legally categorized into reserved forests forming > 60%, minor forests forming about 15%, leaf manure forests (locally known as 'Soppina bettas') form about 5%. Reserved forests (RF) are for the exclusive use of the state, minor forests (MF) are open access for community use and leaf manure forests are assigned to spice garden owners under certain privileges

The vegetation of the district is broadly divided into two zones: the wet evergreen/ semi ever green zone, comprises the areas facing western side from crest line up to the sea and the secondary/ moist deciduous zone, includes area from crest line to the eastern flatter maidan area. Puri (1960) has classified the forests facing the western side as topical wet evergreen type and included the eastern part in the tropical moist deciduous type Champion and Seth (1968) have classified the forests on the western slope as tropical evergreen type and included the forests of the eastern zone in the category of south Indian moist deciduous type According to Arora (1961) following forest types are met in the district: evergreen forests, deciduous forests and scrub forests

Methods

Data on basal area were obtained from eight 1- ha forest plots located in ever green/ semi evergreen and secondary /moist deciduous zone in Uttara Kannada district Of these, two RFs and two MFs were identified to represent each forest zone Brief descriptions on forest sites, land use category, floristic composition, species richness etc , are given in table 1 In all the forest sites all individuals 10 cm girth at breast height (i e., at 132 cm from ground) were marked in 1984 and enumerated as trees Girth measurements in the study plots continued up to 1994.

Above ground standing biomass was estimated from basal area data following Ravindranath *et al.* (2000) Carbon stock in each forest site was estimated assuming that it forms 50% of the biomass. Changes in the biomass and carbon stock in the forest sites after 10 years was computed by deducting the bench mark year values from the final year values/numbers this included recruits also Annual average gain or loss of carbon was calculated dividing the net change by the number of years of observations i e , 10 years

Results

The study sites belonged to different forest types and also different management categories The sites Bhairumbe and Sugavi are MF in moist deciduous zone, while Bidarlli and Sonda belonged to RFs of the same zone. Mirzan and Chandavar are MFs, in evergreen zone and Nagur and Santagal are RFs in the same zone In evergreen zone, the MFs showed lower species diversity as compared to RFs. In terms of number of families in these different zones and differentially managed forests, there was no difference (Table 1).

Basal area, above -ground standing biomass and carbon stocks

Basal area (table 2) varied from 7 69 to 32 62 m^2/ha among the sites during 1984. However, lowest basal area was Mirzan MF (7.69 m^2/ha) and maximum in Sonda RF(32 62 m^2/ha). In general, the average basal area in RFs was 28 03 m^2/ha as compared to MFs 18 38 m^2/ha during 1984. After 10 years, i e., during 1994, results did not change much, wherein Mirzan MF had lowest basal area (6.36 m^2/ha). However, the highest basal area was noticed in Nagur RF (36 92 m^2/ha) as compared to Sonda RF (33 41 m^2/ha). In general, in 1994 also the basal area was higher in RFs (30 98 m^2/ha) than in MFs (17 35 m^2/ha).

Estimated values of biomass in different forest sites during the benchmark year i.e., 1984 and after 10 years are given in table 2. Biomass varied from 100.79 to 263.34 t/ha among the sites during 1984. Lowest biomass was in Mirzan MF (100.79 t/ha) and maximum in Sonda RF (263.34 t/ha). In general, the average biomass in RFs was 233.41 t/ha as compared to MFs 163.79 m^2/ha during 1984. After 10 years, i.e., during 1994, results did not change much, wherein Mirzan MF had lowest biomass (92.12 t/ha). However, the highest biomass was noticed in Nagur RF (291.37 t/ha) as compared to Sonda RF (268.49 t/ha). In general, in 1994 also the biomass was higher in RFs (252.66 t/ha) than in MFs (163.79 t/ha).

Table 3 indicates that carbon stocks ranged from 50.39 to 131.67t /ha, with lowest C-stock in minor forests and maximum in reserve forest category. Carbon stock during the benchmark year was highest in Sonda (131.67 t/ha) RF and lowest in Mirzan MF (50.39 t/ha). In general, the average carbon stock in RFs was 116.7 t/ha as compared to MFs 85.27 t/ha during 1984. Even after 10 years, i.e., during 1994, results did not change much, wherein Mirzan MF had lowest carbon stock (46.12 t/ha). However, the highest carbon stock was noticed in Nagur RF (147.35 t/ha) as compared to Sonda RF (136.33 t/ha). In general, in 1994 also the carbon stock was higher in RFs (126.32 t/ha) than in MFs (81.89 t/ha).

Dynamics of standing biomass and C - Pool

Biomass varied highly in different forest types and management categories (Table 2). The change in biomass was negative in MFs as compared to RFs. The average biomass in the RFs has improved from 233.41 t/ha in 1984 to 252.66 in 1994. However, if the biomass contributed from the new recruits are added, then the total biomass in RFs during 1994 would be 255.51 t/ha. This accounts to 9% increment in the total biomass over 10 years with an annual increment of 2.2 t/ha/year. The rate of increment without new recruits is 1.9 t/ha/year. In the MFs, the trend is negative indicating the extraction of biomass is exceeding the annual growth rates. In MFs the standing biomass has decreased from 170.54 t/ha during 1984 to 167.57 t/ha, with a decrease of 3.03 t/ha over 10 years. It is interesting to note that though the contribution of basal area from new recruits is relatively higher in MFs, but the total basal area in the plot is less. This indicates that though recruitment is occurring in both the forest types, but the extraction may be decreasing the basal area addition in MFs.

C-stock and dynamics in different land use categories

Among different forest categories and management regimes, highest carbon stocks were found in RFs in hilly regions or upghats of the district (Table 4) followed by the RFs in coastal area The pattern of RFs having more carbon stocks is indicated here also. Overall, the RFs have more stocks as compared to the minor forests After 10 years, loss of carbon in minor forests was 0 237% t C/ha/year But in reserve forests it is observed that there was accumulation of carbon at the rate of 1.31 t C/ha/year When the district as a whole is considered it was observed that the forests are fixing carbon at the rate of 1 008 t C/ha/year. Thus an average of 6,33,346.6 t of carbon is assimilated every year from the forests of Uttara Kannada.

Discussion

Higher productivity of tropical forests has made them as carbon sinks assimilating higher carbon-di-oxide that is being emitted globally. There is a growing deforestation of these tropical forests may limit the rates of assimilation thereby enhancing the already increasing CO2 concentration in the atmosphere. The Western Ghats, one of the biodiversity hotspots of the world, the present study indicates that reserve forests in Uttara Kannada are assimilating carbon at the rate of 1.008 t/ha/year This rate, of course, does not involve the herb and shrubs that are normally left out. Thus, the actual potential is much higher than the conservative estimates that are reported here

According to Lugo and Brown (1992), higher values of biomass/C-stock are associated with less human or natural disturbance or better sites, and human disturbed forests will have lower biomass Studying the impact of human disturbance on vegetative carbon storage in forests in China, Wang *et al*, (2001) reported a good negative correlation between C-densities and population densities In the present study, lower biomass/C-stocking in Mirzan and Chandavar MFs could be attributed to human disturbance. Unless altered or disturbed the vegetation / forests continue to accumulate biomass and act as carbon sinks (Clarke 1908) In the present study it was observed that after 10 years accumulation was observed in one minor forest (Sugavi MF) and two reserve forests (Sonda and Nagur RF). Considering the land use categories it was observed that MFs have lost 2.37 t C/ha over 10 years leading to an average annual loss of 0 237 t C/ha/year. Gain of biomass is possible in two ways - through stem growth or by in-growths (recruits). Considering these, it is clear that RFs have accumulated biomass and sequestered 13.09 t C/ha over 10 years period with an annual C-incorporation of 1 31 t C/ ha /year. Phillilps *et al* (1998) reported accumulation of carbon at the rate of 0 74 ±

0.34 t C / ha / year in Neotropical forests. From the present study it is clear that MFs are the sources of atmospheric carbon while RFs are the C-sinks. The over all scenario of the districts is that forests are C-sinks, since the annual rate of C- sequestration is 1.008 t/ha., which is higher than the value reported by Phillips *et al* (1998) for Neotropical forests. It is estimated that 6865.1 million tons of carbon is stored as above ground biomass in Indian forests (Pandey, 2002).

It is interesting to note that in spite of dependence of local people on MFs (and also on RFs) for meeting their requirements such as fuelwood, leaf manure, fodder etc., some of the sites have shown remarkable accumulation of biomass and carbon. According to Montagnini and Porras(1998) mixed species stands have relatively more capacity to produce high level of biomass because of difference in C-fixing rates by the species. Young forest stands and plantations have been shown to grow faster and sequester carbon at faster rate (Shepherd and Motagnini, 2001). Less intra-specific competition following thinning allowed existing trees to grow faster. Disturbance in the forest promotes other species to invade and also prompts existing individuals to grow at faster rate. Recovering forests after previous disturbances accumulate more biomass and carbon (Brown and Lugo, 1990). In the present study all are natural forests with mixed species composition but have undergone disturbances. Such disturbances favoured faster incorporation of carbon in to the forest stand.

Considering the loss of vegetation /forest and emission of carbon to the atmospheric after conversion of forest land, Detwiler and Hall (1998), Houghton (1990), Post *et al* (1990) opined that tropical forests are sources of atmospheric carbon. In the present study it was observed that MFs of the coastal zone and to some extent RFs are subjected to intensive human pressure. According to Ravindranath *et al* (1997), firewood is the dominant fuel for cooking in rural areas. Since the forests are easily accessible, human pressure is more for meeting the requirements. According to Gadgil *et al* (1987), in this locality, 93% of the domestic fuel consumption is the wood fuel. Combustion of fuelwood is an important source of C-emission to atmosphere and it is released through firewood burning. From the present observation, it is clear that MFs are the source of atmospheric C. Thus C-emission exceeded the C-fixing in MFs due to open accessibility. It is clear from the current study that management purpose has played a key role enhancing the carbon accumulation. It is important to note that the MFs, though have experienced a negative trend in carbon accumulation, but the rate of biomass accumulation of new recruits is higher then the RFs indicating that regeneration is higher in MFs Thus, this calls for a strategy to manage the forests in a way that rate of recruitment could be enhanced in order to offset the loss of carbon in the standing stocks

Acknowledgements: We acknowledge the support of Ministry of Environment and Forests the Ford Foundation. We also thank our colleagues Shri P R Bhat, G T Hegde, C. M Shastri, Gopal Hegde, Deepak Shetty and R. M. Furtado for help at various stages.

References

1. Arora, R.K. 1961. The forests of North Kanara district: I Scrubs Journal of Indian Botanical Society, 40(2): 187-200.
2. Brown, S and Lugo, A E , 1982, The storage and production of organic matter in tropical forests and their role in the global carbon cycle, Biotropica, 14: 161-187
3. Brown, S , and Lugo, A E , 1990, Tropical secondary forests, Journal of Tropical Ecology, 6:1-32
4. Brown, S., and Lugo, A.E., 1992, Above ground biomass estimates for tropical moist forests of Brazilian Amazon, Interciencir, 17(1): 8-18
5. Champion, H G , and Seth, S K., 1968, A revised survey of the forest types of India, Govt , of India Press, Nasik, India.
6. Clark, W C , 1982, Carbon dioxide review 1982, Oxford University Press, Oxford.
7. Clarke, F W , 1908, Data on geo-chemistry, US Geological Survey Bulletin 330. Washington
8. Detwiler, R. P., and Hall, C.A.S., 1988, Tropical forests and global carbon cycle, Science, 239: 42-47.
9. Gadgil, M., Hegde, K M., and Bhoja Shetty, K A , 1987, Uttara Kannada: A case study in hill area development, In C J Saldanha (ed.), Karnataka state of Environment Report, 1985-1986, Centre for Taxonomic studies, Bangalore pp 155-172
10. Houghton, R A., 1990, The future role of tropical forests in affecting the carbon dioxide concentration of atmosphere, Ambio, 19: 204-209.
11. Houghton, R.A , 1991, Release of carbon to the atmosphere from degradation of forests in tropical Asia, Can. J Forest Res , 21:132- 142.
12. Lugo, A. E , and Brown, S., 1992, Tropical forests as sinks of atmospheric carbon, Forest Ecology and Forest Management, 54: 239-255

13. Montagnini, F , and Porras, C., 1998, Evaluating the role of plantations as carbon sinks: An example of an integrating approach from the humid tropics, Environmental Management, 22: 459-470.

14. Palm, C. A , Houghton, R. A., Melillo, J. M., and Skole, D L., 1986, Atmospheric carbon dioxide from deforestation in southeast Asia, Biotropica, 18 (3): 177-188

15. Phillips, O., Mahli, Y , Higuchi, N., Laurence, W F., N'unez, P V , Va'squez, R M , Laurence, S G , Ferreira, L V, Stern, M., Brown, S., and Grace, J., 1998, Changes in the carbon balance of tropical forests: Evidence from long-term plots, Science, 282:439-442

16. Post, W. M., Peng, T H., Emauel, W. R., King, A. W., Dale, V. H., and DeAngelis, D L., 1990, The global carbon cycle. American Scientist, 78, 310-326.

17. Puri, G S , 1960, Indian forest ecology Vol I, II. Oxford Book Co., New Delhi, India.

18 Ravindranath, N. H , Murali, K S., and Malhotra, K.C., (eds) 2000, Joint Forest Management and Community Forestry in India: An Ecological and Institutional Assessment Oxford & IBH Publishing Co , New Delhi Pp 318-324.

19 Ravindranath, N H., Somashekhar, B S , and Gadgil, M., 1997, Carbon flow in Indian forests, Climate Change, 35: 297-320

20. Shepherd, D., and Montagnini, F , 2001, Above ground carbon sequestration potential in mixed and pure tree plantations in the humid tropics, Journal of Tropical Forest Science, 13(3): 450 -459.

21. Wang, X., Feng, Z, Ouyang, Z , 2001, The impact of human disturbance on vegetative carbon storage in forest ecosystems in China, Forest Ecology and Management, 148: 117-123.

Table1: Some important characteristics of the study plots located in two vegetation zones of Uttara Kannada district.

Vegetation Zone	Secondary/Moist deciduous zone				Evergreen / Semi evergreen zone			
	Bhairumbe	Sugavi	Bidralli	Sonda	Mirzan	Chandavar	Nagur	Santgal
Land use category	Minor forest	Minor forest	Reserve forest	Reserve forest	Minor forest	Minor forest	Reserve forest	Reserve forest
Level of biotic disturbance	High	High	High	High	Very High	High	Moderate	Minimum
Number of families (during 1984)	23	18	19	24	21	28	29	27
Number of species (during 1984)	40	44	31	51	33	32	51	63
Dominant trees	*Terminalia paniculata* *T. tomentosa* *T. bellerica* *X. xylocarpa* *Phyllanthus emblica* *Ziziphus xylopyrus* *Randia spinosa*	*Terminalia bellerica* *T. paniculata* *T.tomentosa* *Lagerstroemia microcarpa* *Adina cordifolia* *R. spinosa* *P. emblica*	*Xylia xylocarpa* *L. microcarpa* *A.cordifolia* *Schleichera oleosa* *T. paniculata* *R.spinosa*	*Terminala paniculata* *T.tometosa* *X. xylocarpa* *Xantolis tomentosa* *Flacourtia montana* *Ervatamia heyneyana* *A. lindleyana*	*Spondias accuminata* *Alseodaphe semicarpifolia* *Wrightia tomentosa* *E.heyneana* *Ixora Brachiata* *Z. xylopyrus* *R. spinosa*	*Hopea wightiana* *L. microcarpa* *A. semicarpifolia* *lindleyana* *Flacourtia. montana* *Ixora brachiata*	*Hopea wightiana* *Holigarna arnottina* *Pterospermum* sp. *A. lindleyana* *Myrstica attenuata*	*Bishcofia javanica* *Dysoxylum binectariferum* *Nephelium longana* *Nothopodytes foetida* *Nothopegia colebrookiana*
Under growths	*Acacia caesia* *Alangium lamarkii* *Eupatorum odoratum* *Ziziphus oenoplia* *Z. rugosa*	*A. caesia* *Allophyllus cobbe* *Clerodendrum infortunatum* *Murraya koengii* *Pavetta* sp. *Wagatea spicata*	*Allophylus cobbe* *M. koengii* *Breynia* sp. *C.infortunatum* *Eupatorium odoratum*	*Grewia microcos*	*Carissa Caranadas* *Hippocratea* sp. *Hotarrhena antidysenterica* *Z. oenoplia* *Z. rugosa*	*Grewia microcos* *Psychotria flavida* *Strobilanthus* sp. *Uvaria* sp.	*Draecena ternifolia* *Glycosmis pentaphylla* *P.flavida* *Uvaria* sp. *Neolitsea* sp.	*Eugenia macrocephala* *Leea* sp. *Calamus* sp. *Ancestrocladus henyanus* *G. pentaphylla* *Gymnosporia rothiana* *Tarenna zeylanicum*
% composition of evergreen species	26	18	24	47	37	50	66	76
% composition of deciduous species	74	82	76	53	63	50	34	24

Table 2: Estimated basal area (m^2 /ha) and biomass values (t/ha) in different forest sites of Uttara Kannada district.

Forest sites And land use category	Basal area (m^2)		Change Basal Area (%)	Total BA In 1994 including recruits	Net change in BA	Contribution by Recruits	Estimated biomass (t/ha)			Total biomass including recruits
	1984	1994					1984	1994	Change (%)	
Bhairumbe MF	21.59	20.64	-0.95	21.43	-0.16	0.79	191.42	185.23	-6.19	190.38
Sugavi MF	22.52	23.89	1.37	25.11	2.59	1.22	197.49	206.42	8.93	214.37
Bidralli RF	26.42	24.66	-1.76	25.11	-1.31	0.45	222.91	211.44	-11.47	214.37
Sonda RF	32.62	33.41	0.79	34.05	1.43	0.64	263.34	268.49	5.15	272.66
Mirzan MF	7.69	6.36	-1.33	6.38	-1.31	0.02	100.79	92.12	-8.67	92.25
Chandavar MF	21.75	18.52	-3.23	18.81	-2.94	0.29	192.47	171.41	-21.06	173.3
Nagur RF	20.95	36.92	15.97	37.43	16.48	0.51	187.25	291.37	104.12	294.7
Santagal RF	32.13	28.94	-3.19	29.09	-3.04	0.15	260.14	239.34	20.8	240.32
Average of MF	18.38 ± 7.14	17.35 ± 7.65	-1.03 ± 1.88	17.93 ± 8.12	-0.45 ± 2.32	0.58 ± 0.53	170.54 ± 46.57	163.79 ± 49.90	-6.74 ±12.31	167.57 ± 52.96
Average of RF	28.03 ± 5.49	30.98 ± 5.33	2.95 ± 8.83	31.42 ± 5.42	3.39 ± 8.91	0.43 ± 0.21	233.41 ± 35.82	252.66 ± 34.76	29.65 ± 51.36	255.51 ± 31.37
t-value for MF & RF	2.14	2.92	0.88	2.76	0.83	0.498	2.14	2.92	1.38	2.76
P value	0.07	0.03	0.44	0.03	0.46	0.644	0.07	0.03	0.26	0.03

Table 3: Estimated carbon stock (t/ha) & C- Dynamics (t/ha/year) in different forest sites in Uttara Kannada district of the Western Ghats.

Forest site & Land use category	Estimated C-Stock during		Change in C-stock (%)	C-stock during 1994 including recruits	Net change in C-stock (%)	Annual carbon loss / gain (%)
	1984	1994				
Bhairumbe MF	95.72	92.61	-3.1	95.19	-0.52 (-0.54)	-0.052 (-0.054)
Sugavi MF	98.74	103.21	4.47	107.18	+8.44 (+8.54)	+0.844 (+0.85)
Bidralli RF	111.45	105.72	-5.73	107.18	-4.27 (-3.83)	-0.427 (-0.38)
Sonda RF	131.67	134.24	2.57	136.33	+4.66 (+3.53)	+0.466 (+0.35)
Mirzan MF	50.39	46.06	-4.33	46.12	-4.27 (-8.47)	-0.427 (-0.84)
Chandavar MF	96.23	85.7	-10.53	86.65	-9.58 (-9.95)	-0.958 (-0.99)
Nagur RF	93.62	145.68	52.06	147.35	+53.73 (+57.39)	+5.373 (+5.73)
Santagal RF	130.07	119.67	-10.4	120.16	-9.91 (-7.61)	-0.991 (-0.76)
Average MFs (mean ± SD)	85.27± 23.29	81.89 ± 24.95	-3.37 ± 6.95	83.79 ± 26.48	-1.48 ± 7.48	-0.15 ± 0.758
Average RFs (mean ± SD)	116.70 ± 17.91	126.32 ± 17.37	9.62 ± 28.79	127.75 ± 17.68	11.05 ± 29.07	1.11 ± 2.09
t-value between mean of RF and MF	2 13	2 92	0 88	2 76	0 83	0 83
P value	0.07	0.03	0.44	0.03	0.46	0.46

Table 4: Estimated carbon stock (t/ha) & C- Dynamics (t/ha/yr) in different forestland use types and in Uttara Kannada district of the Western Ghats. Averages for each forest type is weighted average using the mean of that area from the sample plots and the area of the forest type in that region[i]

Forest site & Land use category	Estimated C-Stock during		Change in C-stock	C-stock during 1994 including recruits	Net Change in C - stock (%)	Annual loss/gain of carbon (%)
	1984	1994				
Average of MFs of hilly (upghat) area	97.22	97.95	0.69	101.18	+3.96 (+4.07)	+0.396
Average of RFs of hilly (upghat) area	121.56	119.98	-1.58	121.75	-0.19 (-0.15)	-0.019
Average of hilly (upghat) area	101.51	101.79	0.286	104.80	3.297 (+3.24)	+0.3297
Average of MFs of Coastal Area	73.35	65.88	-7.43	66.38	-6.93 (-9.45)	-0.692
Average of RFs of Coastal Areas	111.84	132.67	20.83	133.75	+21.91 (+19.59)	+2.191
Average for Coastal area	81.44	79.97	-1.47	80.60	-0.84 (-1.032)	-0.084
Average of MFs of Uttara Kannada district	83.32	79.28	-4.04	80.95	-2.37 (-2.84)	-0.237
Average of RFs of Uttara Kannada District	106.94	118.04	11.09	120.04	13.09 (12.23)	1.31
Uttara Kannada district average	102.34	110.49	8.14	112.42	10.08 (9.84)	1.008

[i] According the Karnataka Forest Department records, 505920 ha of land is under RF and 122400 ha of MF in Uttara Kannada district. In coastal zone, 266176 ha is designated as RF and 71187 ha is under MF. Similarly, 239744 ha is under RF and 51213 ha is under MF in the upghat or hilly zone of the district.